

Research: Health Economics

Impact of diabetes on healthcare costs in a population-based cohort: a cost analysis

L. C. Rosella^{1,2,3}, M. Lebenbaum², T. Fitzpatrick², D. O'Reilly^{4,5}, J. Wang², G. L. Booth^{3,6,7,8}, T. A. Stukel^{3,8} and W. P. Wodchis^{3,8,9}

¹Dalla Lana School of Public Health, University of Toronto, Toronto, ²Public Health Ontario, Toronto, ³Institute for Clinical Evaluative Sciences, Toronto, ⁴Department of Clinical Epidemiology and Biostatistics, McMaster University, Hamilton, ⁵PATH Research Institute, St Joseph's Healthcare, Hamilton, ⁶Department of Medicine, University of Toronto, Toronto, ⁷St. Michael's Hospital, Toronto, ⁸Institute of Health Management Policy and Evaluation, University of Toronto and ⁹Toronto Rehabilitation Institute, Toronto, Canada

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Abstract

Aims To estimate the healthcare costs attributable to diabetes in Ontario, Canada using a propensity-matched control design and health administrative data from the perspective of a single-payer healthcare system.

Methods Incident diabetes cases among adults in Ontario were identified from the Ontario Diabetes Database between 2004 and 2012 and matched 1:3 to control subjects without diabetes identified in health administrative databases on the basis of sociodemographics and propensity score. Using a comprehensive source of administrative databases, direct per-person costs (Canadian dollars 2012) were calculated. A cost analysis was performed to calculate the attributable costs of diabetes; i.e. the difference of costs between patients with diabetes and control subjects without diabetes.

Results The study sample included 699 042 incident diabetes cases. The costs attributable to diabetes were greatest in the year after diagnosis [C\$3,785 (95% CI 3708, 3862) per person for women and C\$3,826 (95% CI 3751, 3901) for men], increasing substantially for older age groups and patients who died during follow-up. After accounting for baseline comorbidities, attributable costs were primarily incurred through inpatient acute hospitalizations, physician visits and prescription medications and assistive devices.

Conclusions The excess healthcare costs attributable to diabetes are substantial and pose a significant clinical and public health challenge. This burden is an important consideration for decision-makers, particularly given increasing concern over the sustainability of the healthcare system, aging population structure and increasing prevalence of diabetic risk factors, such as obesity.

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Introduction

Diabetes represents one of the greatest public health and health system challenges of the 21st century [1]. Diabetes decreases quality and length of life, and is associated with numerous complications, particularly cardiovascular events such as myocardial infarction, stroke and heart failure [2,3]. Despite treatment and management advances, diabetes remains the leading cause of renal failure, lower limb amputation and blindness among adults [4,5]. As of 2014, the number of prevalent diabetes cases in Canada was 3.3

million, with the age-standardized prevalence of diabetes increasing by 70% over the past decade [6–8]. Globally, 200 million people are estimated to have diabetes [9]. As a result of population aging, rising prevalence of obesity, increasingly sedentary lifestyles and decreases in mortality rates among individuals with diabetes, the global prevalence of diabetes is expected to continue rising [10,11].

Largely because of the costs incurred through complications, diabetes is one of the most costly health conditions to manage. The Canadian Diabetes Association estimated that the direct health system costs of diabetes in Ontario were C \$5.8 bn in 2014, which is expected to rise to C\$7.6 bn by 2024, with overall costs (including indirect costs) reaching an estimated C\$16 bn [6,12]. In the USA, estimates of the total direct costs of diabetes are much higher: a staggering US\$176 bn, as of 2012 [13]. It is further estimated that the lifetime

Correspondence to: Laura C. Rosella. E-mail: laura.rosella@utoronto.ca
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What's new?

- Using a validated, population-based registry, we created the largest propensity-matched cohort (almost 3 million people) to provide comprehensive and current estimates of the healthcare costs attributable to diabetes.
- The attributable costs were estimated using a newly developed person-centred costing methodology, representing the most comprehensive healthcare costs published. Attributable costs were ~C\$10,000 per-person over the study follow-up, with nearly C\$4,000 being spent during the year after diagnosis.
- The excess healthcare costs attributable to diabetes reported in this study could be useful for allocating resources for diabetes and for accurate inputs into economic evaluations of diabetes intervention and management.

healthcare costs of diabetes in the USA are US\$85,200 [14]. Estimates of attributable diabetes costs are limited, particularly in Canada. Previous costing studies have not comprehensively estimated costs, have lacked a control group or have had limited control over confounding between cases and controls [11,15–18]. Because healthcare systems are managed and funded at the provincial level in Canada, it is important to also have province-specific estimates. Additionally, there has been a recent decline in mortality rates among individuals with diabetes and, if attributable to changes in diabetes management rather than disease duration, this may influence attributable healthcare costs [10]. Current estimates of the attributable costs of diabetes are therefore needed to inform health decision-makers of the economic burden diabetes places on the Canadian healthcare system, to guide economic evaluations of diabetes prevention strategies and to allocate scarce health resources efficiently. The objective of the present study was to estimate the current attributable costs of diabetes in Ontario, Canada's most populous province, using comprehensive administrative data from the perspective of a single-payer healthcare system.

Methods

We used a propensity-matched cohort design to estimate the attributable costs for all incident adult cases of diabetes identified in Ontario from 1 April 2004 to 31 March 2012. Total annual healthcare costs were tracked using comprehensive administrative databases, and total cumulative costs for the 8 years of follow-up were calculated. Incident cases of diabetes were identified from the Ontario Diabetes Database, the provincial component of the National Diabetes Surveillance System, which contains all physician-diagnosed diabetes cases identified in Ontario [19]. The

Ontario Diabetes Database uses the diagnostic criteria of two physician claims recorded in the Ontario Health Insurance Program (OHIP) or one hospital discharge in a 2-year period, and has a demonstrated sensitivity of 86% and specificity of 97% [19]. All women with gestational diabetes, i.e. those with a diabetes diagnostic code followed by physician visit or hospital discharge within 5 months of an obstetrical event, are excluded from the Ontario Diabetes Database. The index date was the date of the first OHIP claim or date of hospital discharge. We restricted our sample to adults aged ≥ 20 years who were not diagnosed with diabetes at baseline (i.e. prevalent diabetes). We further excluded individuals who were not found in the Registered Persons Database, i.e. not registered for the OHIP, had a death date before the index date (according to the Registered Persons Database), or who had missing data on matching variables.

Incidence density sampling was used to identify a control cohort of people without diabetes from administrative databases, excluding patients in the Ontario Diabetes Database; the control cohort was randomly assigned index dates according to the sex-specific distribution of index dates among cases. We hard-matched cases 1:3 with controls on index date (± 30 days), age (± 90 days), and the logit of the propensity score with a caliper width of 0.2 using a greedy matching algorithm without replacement. We excluded cases that could not be matched to three controls; i.e. were matched to two or fewer controls. To estimate the propensity score, we conducted a logistic regression of case status including age, rurality (Rurality Index for Ontario), comorbidity at baseline as measured by the collapsed Aggregated Diagnosis Groups, geographic location as measured by the Local Health Integration Network of residence, and neighbourhood income quintile. Rurality Index for Ontario, Local Health Integration Network and neighbourhood income quintile were estimated using the postal code at the index date and census data. Aggregated Diagnosis Groups have been previously validated for use in the adult population of Ontario [20]; collapsed Aggregated Diagnosis Groups were estimated for the 2-year period before the index date.

Healthcare costs

We captured direct healthcare costs (for 2004–2012) from the health system perspective using a validated and comprehensive person-centred costing methodology developed for the Ontario health administrative data [21]. This methodology captures all relevant costs covered under Ontario's single-payer health insurance plan, including those attributable to inpatient hospitalizations, emergency department visits, same day surgery, dialysis, oncology clinic visits, fee-for-service physician and non-physician services, non-fee-for-service physicians, prescription medications, laboratory, rehabilitation, complex continuing care, long-term care, mental health inpatient stays, home care services and medical devices.

Inpatient hospitalizations, emergency department visits and same day surgery costs were calculated according to

Resource Intensity Weight methodology, multiplying the individual case Resource Intensity Weight by the average provincial costs per weighted case (weighted by case mix groups) [21]. Costs for dialysis and outpatient oncology visits, were calculated using analogous Comprehensive Ambulatory Classification System weights [22]. Fee-for-service physician and non-physician service costs were captured through OHIP payments. Non-fee-for-service physician payments were calculated by applying applicable capitation payments or other fees based on individuals listed in the Primary Care Model Roster from the Client Agency Program Enrolment database. Prescription medication costs for those eligible for the Ontario Drug Benefit Plan were captured through pharmacy payments in the Ontario Drug Benefit database. Costs for the interpretation of diagnostic or laboratory work on outpatients are captured within OHIP data; however, laboratory and diagnostic technology costs performed within a hospital are not captured on a per-patient basis. Rehabilitation costs were based on length of stay and case mix [23–25]. Complex continuing care and inpatient psychiatric costs were based on case mix, number of days in care, and Resource Utilization Groups [21,26]. Long-term care and home care costs were calculated according to average cost per day or hour, respectively [27]. Costs for high-cost medical device equipment, such as wheelchairs and insulin pumps, were captured using the Assistive Devices Program database according to amount paid (directly to patients). All unit costs were obtained from the Ministry of Health and Long-Term Care, Ontario's healthcare payer; weighting values were supplied by the Ministry of Health and Long-Term Care and Canadian Institute for Health Information. Specific details regarding this methodology, including exact unit costs (from 2003/2004 onwards) and weighting values, are documented in detail elsewhere [19].

Analysis

We assessed the quality of matching by comparing the means and proportions of all matching variables between unmatched and matched samples. Standardized differences and variance ratios were assessed, where standardized differences of ≥ 0.1 suggest a significant imbalance occurred [27]. We calculated the mean annualized costs (and standard deviations) for cases and controls by summing total costs across all years and dividing by total follow-up time. All costs are reported in 2012 Canadian dollars (\$C). We estimated attributable per-person costs as the difference in healthcare costs between diabetes cases and matched non-diabetes controls [28]. Because of the skewed distribution of costs, we used a mixed model with an exchangeable correlation matrix to estimate 95% CIs of differences. Attributable per-person costs were stratified across age at

the index date (20–44, 45–64, 65–74, 75–84, ≥ 85 years), survival during follow-up, and time since index date. All analyses, including development of propensity score models, matching and estimation of attributable costs, were sex-stratified.

All statistical analyses were performed using SAS version 9.3 (SAS Institute Inc., Cary, NC, USA).

Results

A total of 699 042 incident (newly diagnosed) cases of diabetes were identified between 2004 and 2012. A total of 775 cases, representing 0.11% of total incident cases, could not be matched to three non-diabetes controls; i.e. could only be matched to two or fewer controls. These unmatched cases were significantly older with smaller propensity scores, including a greater frequency of each collapsed Aggregated Diagnosis Group (except pregnancy), compared with unmatched controls (Table 1). Matched cases and controls were identical in terms of all matching variables (age, follow-up time and propensity score); no significant imbalances occurred during matching.

Over the entire 8 years of follow-up, the average per-person healthcare spending for diabetes cases was more than twice that of non-diabetes controls (C\$16,145 vs. C\$6,414 for women and C\$16,356 vs. \$6,041 for men); the overall per-person attributable costs associated with diabetes were C\$9,731 for women (95% CI 9451–10,012) and \$10,315 for males (95% CI 10,016–10,613; Table 2). Meaning, over the 8 years of follow-up, incident diabetes was associated with ~C\$10,000 in excess healthcare costs. Attributable diabetes costs were significantly greater in the year after index date (e.g. diabetes diagnosis), stabilized in years 2–7, and significantly declined in year 8. Costs for both cases and controls increased drastically in older age groups and for patients who died during follow-up; however, in both cases, healthcare costs were substantially greater for diabetes cases. The per-person attributable costs of diabetes for patients aged ≥ 85 years were \$43,575 for women (95% CI 41,245–45,906) and \$56,714 for men (95% CI 52,767–60,663). For patients who died during follow-up, attributable diabetes costs were substantial: \$85,291 (95% CI 82,027–88,402) and \$90,294 (95% CI [86,864–93,509]) for women and men, respectively.

Furthermore, attributable healthcare costs occurred mainly through acute inpatient hospitalizations, accounting for >50% of attributable costs in incident diabetes cases (Fig. 1). Physician costs consistently accounted for ~20% of annual healthcare costs attributable to diabetes. Prescription medication and assistive devices also accounted for 22% of attributable costs following the first year; however, they accounted for only 8% of attributable costs among incident diabetes cases.

Table 1 Baseline characteristics of matching variables for unmatched and matched cases and controls, by sex

Variable	Unmatched		Absolute standardized difference	Variance ratio	Matched		Absolute standardized difference	Variance ratio
	Cases	Controls			Cases	Controls		
Women								
Total, N	410	615*			331 232	993 639		
Mean (sd) age	58.80 (15.51)	46.89 (17.62)	0.72	0.77	58.78 (15.49)	58.78(15.49)	0.00	1.00
Age, n (%)								
20–44 years	18.53	49.46	0.69	0.60	18.53	18.53	0.00	1.00
45–64 years	44.93	33.28	0.24	1.11	44.96	44.96	0.00	1.00
65–74 years	19.31	8.43	0.32	2.02	19.31	19.31	0.00	1.00
75–84 years	12.76	6.04	0.23	1.96	12.76	12.77	0.00	1.00
≥85 years	4.48	2.80	0.09	1.57	4.43	4.43	0.00	1.00
Mean (sd) follow-up, years	3.83 (2.27)	3.93 (2.24)	0.04	1.02	3.83 (2.27)	3.89 (2.24)	0.03	1.02
Mean (sd) propensity score	2.40 (0.72)	3.19 (0.88)	0.98	0.67	2.4 (0.72)	2.41 (0.72)	0.01	1.00
Collapsed Aggregated Diagnosis Group, %								
Acute minor	80.06	64.89	0.35	0.7	80.04	80.38	0.02	1.01
Acute major	79.77	61.73	0.41	0.68	79.75	80.14	0.00	1.00
Likely to recur	66.93	54.21	0.26	0.89	66.91	67.05	0.04	1.25
Asthma	9.20	5.38	0.15	1.64	9.13	8.15	0.01	1.01
Chronic medical: unstable	40.96	20.37	0.46	1.49	40.90	38.57	0.01	1.01
Chronic medical: stable	73.88	38.23	0.77	0.82	73.86	74.14	0.00	1.00
Chronic specialty: stable	6.39	3.78	0.12	1.64	6.39	6.32	0.04	1.11
Eye/dental	14.60	7.62	0.22	1.77	14.59	13.82	0.05	1.02
Chronic specialty: unstable	12.24	6.67	0.19	1.72	12.24	11.92	0.01	1.01
Psychosocial	39.19	28.32	0.23	1.17	39.13	38.32	0.00	1.01
Preventive/administrative	50.58	46.05	0.09	1.01	50.58	50.48	0.02	1.05
Pregnancy	3.62	6.87	0.15	0.54	3.62	2.88	0.01	1.02
Men								
Total, N	365	508*			367 035	1 101 105		
Mean (sd) age	57.61 (13.83)	45.49 (16.48)	0.80	0.70	57.59 (13.8)	57.59 (13.8)	0.00	1.00
20–44 years	17.55	51.61	0.77	0.58	17.55	17.55	0.00	1.00
45–64 years	51.06	34.28	0.34	1.11	51.09	51.10	0.00	1.00
65–74 years	19.11	7.92	0.33	2.12	19.13	19.12	0.00	1.00
75–84 years	10.00	4.72	0.20	2.00	10.00	10.00	0.00	1.00
≥85 years	2.28	1.47	0.06	1.54	2.23	2.23	0.00	1.00
Mean (sd) follow-up, years	3.80 (2.25)	3.90 (2.23)	0.04	1.02	3.89 (2.25)	3.86 (2.22)	0.03	1.02
Mean (sd) propensity score	2.23 (0.72)	3.04 (0.86)	1.02	0.70	2.24 (0.72)	2.25 (0.72)	0.01	1.00
Collapsed Aggregated Diagnosis Group, %								
Acute minor	72.23	54.71	0.37	0.81	72.21	72.30	0.00	1.00
Acute major	70.83	48.17	0.47	0.83	70.81	70.98	0.00	1.00
Likely to recur	58.21	41.05	0.35	1.01	58.19	58.04	0.00	1.00
Asthma	5.76	3.67	0.10	1.54	5.73	5.14	0.03	1.11
Chronic medical: unstable	40.87	17.90	0.52	1.64	40.82	37.54	0.07	1.03
Chronic medical: stable	67.25	31.78	0.76	1.02	67.23	67.41	0.00	1.00
Chronic specialty: stable	6.37	3.91	0.11	1.59	6.37	6.46	0.00	0.99
Eye/dental	11.40	5.98	0.19	1.80	11.39	10.53	0.03	1.07

Table 1 (Continued)

Variable	Unmatched				Matched			
	Cases	Controls	Absolute standardized difference	Variance ratio	Cases	Controls	Absolute standardized difference	Variance ratio
Chronic specialty: unstable	9.91	5.34	0.17	1.76	9.91	9.68	0.01	1.02
Psychosocial	30.53	19.96	0.25	1.33	30.49	29.43	0.02	1.02
Preventive/administrative	45.16	27.91	0.36	1.23	45.13	44.88	0.01	1.00

*Difference between total matched controls and total number of controls matched to a case with three matched controls.

Discussion

An estimated 1.5 million adults in Ontario currently have diabetes, and this number is expected to rise by 50% over the next decade [7,8]. Declining mortality rates for patients with diabetes, aging population demographics, and increasing prevalence of diabetes risk factors (e.g. overweight and obesity, sedentary lifestyles and metabolic syndrome) will continue to drive the diabetes epidemic. By propensity-matching diabetes cases to non-diabetes controls, we were able to disaggregate the total excess healthcare costs attributable to diabetes. We found that the healthcare costs attributable to diabetes are substantial and are particularly high for older patients, those that died during follow-up, and for incident (newly-diagnosed) diabetes cases. We also found that, even after adjusting for various sociodemographic factors and baseline comorbidity, attributable diabetes costs most commonly occurred through hospitalizations, physician visits and prescription medications and medical devices, with the latter accounting for a larger proportion of costs among prevalent diabetes costs compared with incident cases.

It may be expected that total and attributable healthcare costs would increase over time as health status presumably declines, clinical illness progresses, complications develop and other comorbidities develop or deteriorate. However, we observed that, after a large spike in costs during the incident year, costs were fairly stable for the following years. These results may reflect changes in hospital length of stay, health service use intensity, and increased medication use, be it antidiabetic or cardiovascular risk reduction medication, among prevalent diabetes cases [15,17,18]. Further, it is possible that these trends may be an artifact of survivorship bias, in which healthy patients are the ones more likely to survive until the end of the study period [15].

To our knowledge, only two reports have provided comprehensive estimates of the total direct and attributable healthcare costs of diabetes in Ontario. In 2009, the Canadian Diabetes Association released a series of province-specific reports on the cost of diabetes [7,8]. These

reports used the National Diabetes Surveillance System and the Canadian Diabetes Cost Model to estimate the current costs and project the future total costs of diabetes, nationally and provincially. For 2010, the direct healthcare costs of diabetes in Ontario were estimated at C\$4.9 billion, with 22% accrued through hospitalizations. These estimates were based on limited administrative databases and did not use a control cohort to estimate attributable diabetes costs. Another study, by Goeree *et al.* [28] reported estimates and distributions of attributable healthcare costs for incident diabetes between 1994 and 2005 similar to those in the present study. The present study builds on that work by providing contemporary estimates based on a larger sample, matching three controls per case to allow more precise estimates, and uses comprehensive person-centred costing methodology which incorporates more relevant sources of health expenditures. Additionally, we provide estimates specific to all relevant healthcare sectors.

A considerable strength of our study design is that we identified all incident diabetes cases in Ontario from 2004 to 2012 using a validated, population-based administrative diabetes registry [19]. Additionally, by using a comprehensive source of health administrative databases in the context of a single-payer system, this study is unique in that these estimates of attributable diabetes costs reflect actual healthcare delivery, use and spending in Ontario, as opposed to modelled projections. The study design is further strengthened by our use of a large, 1:3 controlled, propensity-score matched cohort to estimate the total and annual per-patient healthcare costs attributable to diabetes. Many previous diabetes costing studies did not use a control group and have probably overestimated the excess healthcare costs attributable to diabetes, which may bias the results of any economic evaluations and modelling studies using these estimates [29]. Furthermore, our study design was not limited to only those patients who survived all 8 years; thus, we have produced estimates that are more reflective of patients actually receiving diabetes management and care. These cost estimates are therefore less affected by survivorship bias than they would have been had these patients been excluded; i.e.

Table 2 The direct (per-person) healthcare costs (Canadian dollars 2012) for diabetes cases and non-diabetic controls and attributable (annualized) healthcare costs for the entire 8-year follow-up period overall and by year since index (annual costs), age at baseline and survival status, for males and females

	Women						Men					
	Costs: diabetes cases, C\$			Costs: controls, C\$			Costs: diabetes cases, C\$			Costs: controls, C\$		
	Mean	SD	(95% CI)	Mean	SD	(95% CI)	Mean	SD	(95% CI)	Mean	SD	(95% CI)
Overall	16 145	82 548	(9451, 10 012)	6414	20 787	(9451, 10 012)	16 356	92 312	(10 016–10 613)	6041	23 064	(10 016–10 613)
Year post-index (annual costs, C\$)												
Year 1	8160	22 217	(3708–3862)	4375	12 821	(3708–3862)	7699	22 649	(3751–3901)	3873	13 197	(3751–3901)
Year 2	5682	15 351	(1176–1295)	4463	12 893	(1176–1295)	4949	15 832	(945–1064)	3953	13 623	(945–1064)
Year 3	5603	15 346	(1034–1164)	4521	13 139	(1034–1164)	4768	15 025	(672–798)	4040	14 220	(672–798)
Year 4	5609	14 794	(935–1077)	4616	13 675	(935–1077)	4908	15 969	(720–868)	4120	14 451	(720–868)
Year 5	5630	14 977	(928–1090)	4634	13 879	(928–1090)	4921	15 366	(736–897)	4106	14 193	(736–897)
Year 6	5386	14 510	(861–1043)	4446	13 298	(861–1043)	4676	15 051	(718–902)	3866	14 130	(718–902)
Year 7	4928	13 856	(790–1008)	4041	12 287	(790–1008)	4272	13 950	(666–880)	3499	12 661	(666–880)
Year 8	3490	10 586	(512–756)	2860	9455	(512–756)	3004	10 552	(432–673)	2453	9757	(432–673)
Age at baseline												
20–44 years	5588	42 592	(3224–3902)	2025	9737	(3224–3902)	5816	57 434	(3871–4761)	1499	9081	(3871–4761)
45–64 years	9086	64 835	(5321–5984)	3434	14 836	(5321–5984)	9919	76 238	(6079–6774)	3492	15 689	(6079–6774)
65–74 years	17 403	84 584	(8994–10 320)	7746	23 748	(8994–10 320)	21 302	102 725	(11 452–12 989)	9082	29 027	(11 452–12 989)
75–84 years	36 014	127 701	(20 199–22 651)	14 589	30 311	(20 199–22 651)	43 277	141 718	(25 263–28 189)	16 550	38 837	(25 263–28 189)
≥85 years	69 229	143 051	(41 245–45 906)	25 655	35 734	(41 245–45 906)	83 775	180 727	(52 767–60 663)	27 060	47 494	(52 767–60 663)
Survival status during follow-up												
Survived	6462	19 945	(2421–2565)	3979	10 146	(2421–2565)	5939	22 379	(2429–2583)	3437	9997	(2429–2583)
Died	129 133	260 428	(82 027–88 402)	43 842	63 249	(82 027–88 402)	134 197	290 068	(86 864–93 509)	43 903	72 662	(86 864–93 509)

* Mean cost diabetes cases minus mean costs matched controls.

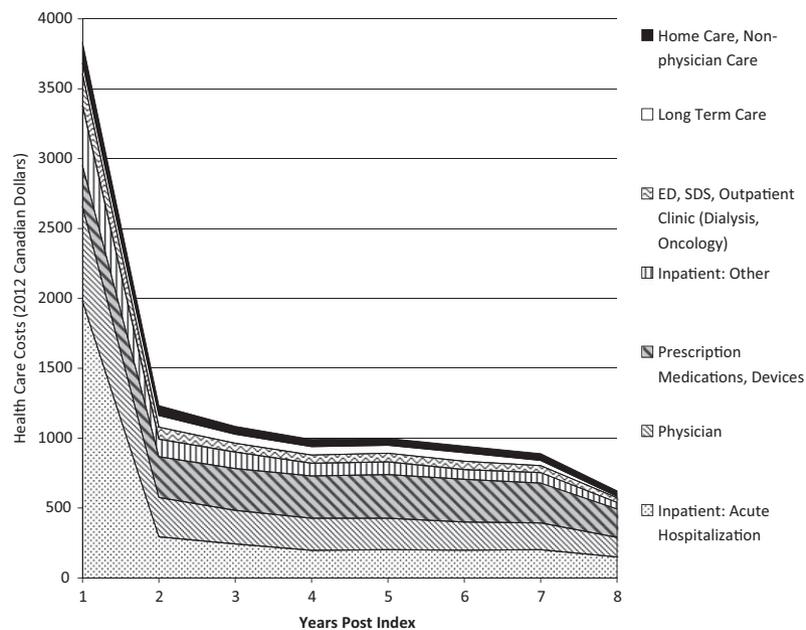


FIGURE 1 Sector-specific per-person healthcare costs (\$CAD 2012) attributable to diabetes by year since index.

patients living until the end of the study tend to be healthier, on average, than the overall cohort.

The study also has some limitations. Given that we relied on health administrative databases to identify diabetes cases, albeit using a highly sensitive and specific diagnostic algorithm, there is the potential that some diabetes cases were not identified. Any people with currently undiagnosed diabetes and those who do not have encounters with the healthcare system will not be captured by this study. It is, therefore, likely that the estimates provided here are underestimations of the total healthcare costs attributable to diabetes. Furthermore, it is currently not possible to distinguish Type 1 from Type 2 diabetes cases using the Ontario Diabetes Database; however, >95% of total diabetes cases are Type 2 diabetes [7]. We restricted incident cases to the adult population to reduce the likelihood that incident Type 1 diabetes cases would be included. Another limitation to acknowledge is the possibility that additional confounders, outside of the characteristics available through administrative databases (e.g. BMI) may be present in the matched cohort and that these factors may drive differences in healthcare use and spending. Similarly, healthcare billing for First Nations people in Ontario is not included in the available OHIP health administrative databases (such care is covered by the non-Insured Health Benefits Program). Consequently, it is difficult to track healthcare spending for First Nations or to link with health services use. Given that First Nations people are also more likely to develop diabetes than the general Ontario population, these results may not generalize to First Nations people [17] and they should be a focus of future studies. Finally, while OHIP coverage is

comprehensive, there are certain services and costs not covered. These include out-of-pocket medication costs for diabetes [7], as prescription medication costs are captured only for individuals who are eligible for Ontario Drug Benefit (i.e. aged ≥ 65 years, residents living in institutions, persons receiving social assistance or whose drug costs are high relative to total income). The Canadian Diabetes Association has estimated the annual out-of-pocket costs to be \sim C\$2,600 for a patient with Type 2 diabetes living in Ontario (based on an annual income of C\$43,000 in 2011) [7,30]. As such, our estimates are probably more conservative than the actual attributable healthcare costs of diabetes; however, this analysis took the perspective of the healthcare system, making this a minor limitation to our study design. We acknowledge that, by taking the perspective of the healthcare system, patient costs such as these were not considered; however, we anticipate that our study design and the scope of the data used have provided comprehensive estimates of the direct healthcare costs attributable to diabetes.

In conclusion, the attributable healthcare costs of diabetes are substantial. We found that the per-person attributable costs for diabetes cases, compared with matched controls, were \sim \$10,000 over the 8 years of follow-up, with nearly \$4,000 being spent during the first year after diabetes diagnosis. Even when accounting for baseline sociodemographic factors and comorbidity, attributable diabetes costs were greatest for incident cases, increased with age and were largely incurred through acute hospitalization, physician services and prescription medications and assistive devices. Considering there were \sim 76 700 incident diabetes cases in Ontario during 2011–2012, our

results suggest that the overall attributable healthcare costs for incident cases of diabetes that year were C\$292 m. The excess healthcare costs attributable to diabetes are not trivial and are an important consideration for both healthcare and public health decision-makers, particularly given increasing concern over sustainability of the healthcare system, aging population dynamics, and increasing prevalence of diabetes risk factors, such as overweight and obesity, sedentary lifestyles and metabolic syndrome. Current estimates of the healthcare costs attributable to diabetes are necessary to assess the financial burdens placed on the healthcare system, allocate scarce resources and inform economic evaluations of diabetes prevention and management initiatives.

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Competing interests

None declared.

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